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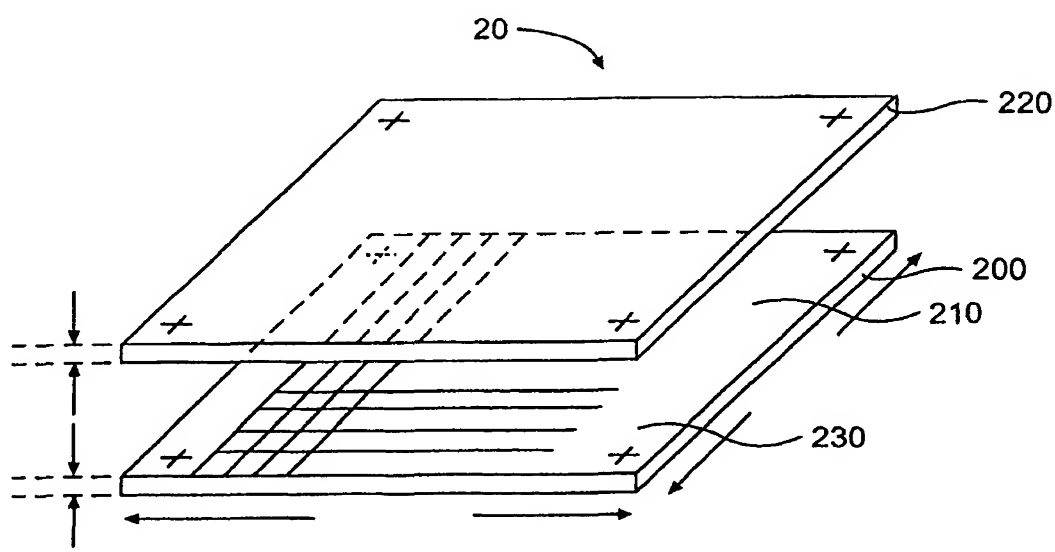

(57) Abstract

A color organic light–emitting diode (OLED) display device is disclosed. The OLED display device comprises a silicon substrate (200) with a plurality of integrated OLED drivers (205) arranged in a matrix; a hydrophobic, transparent passivation layer (210); color filter or color changing media (230) patterned on the passivation layer (210); and a glass cover (220) for protecting the OLED drivers (205), passivation layer (210), and color filter or color changing media (230). The passivation layer (210) permits lithographic patterning of the color filter or color changing media (230) using wet processing methods. In an alternate embodiment, a getter layer (240) is formed on the substrate (200) and OLED drivers (205). The passivation layer (210) is then formed on the getter layer (240). A method for fabricating a color OLED display device with a passivation layer (210) and color filter or color changing media (230) is also disclosed.

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COLOR ORGANIC LIGHT-EMITTING DEVICE STRUCTURE AND METHOD OF FABRICATION

Cross-Reference to Related Applications

This application relates to and claims priority on United States Provisional Application Serial No. 60/101,428, filed September 22, 1998 and entitled "Color Organic Light-Emitting Device Structure."

Field of the Invention

The present invention relates to color organic light-emitting diode (OLED) video displays. In particular, the present invention is directed to a color OLED display provided with a hydrophobic, transparent passivation layer disposed on the OLED layers and substrate.

Background of the Invention

Organic light-emitting diodes ("OLEDs") have been known for approximately two decades. All OLEDs work on the same general principles. One or more layers of semiconducting organic material are sandwiched between two electrodes. An electric current is applied to the device, causing negatively charged electrons to move into the organic material(s) from the cathode. Positive charges, typically referred to as holes, move in from the anode. The positive and negative charges meet in the center layers (i.e., the semiconducting organic material), combine, and produce photons. The wave-length -- and consequently the color -- of the photons depends on the electronic properties of the organic material in which the photons are generated.

In a typical OLED, one of the electrodes is transparent. The cathode may be constructed of a low work function material. The holes may be injected from a high work function anode material into the organic material. Typically, the devices operate with a DC bias of from 2 to 30 volts. The films may be formed by evaporation, spin casting or other appropriate polymer film-forming techniques, or chemical self-assembly. Thicknesses typically range from a few mono layers to about 1 to 2,000 Angstroms.

OLEDs typically work best when operated in a current mode. The light output is much more stable for constant current drive than for a constant voltage drive. This is in contrast to

many other display technologies, which are typically operated in a voltage mode. An active matrix display using OLED technology, therefore, requires a specific pixel architecture to provide for a current mode of operation.

In a typical matrix-addressed OLED display, numerous OLEDs are formed on a single substrate and arranged in groups in a regular grid pattern. Several OLED groups forming a column of the grid may share a common cathode, or cathode line. Several OLED groups forming a row of the grid may share a common anode, or anode line. The individual OLEDs in a given group emit light when their cathode line and anode line are activated at the same time.

An OLED may be designed to be viewed either from the "top" -- the face opposite the foundational substrate -- or from the "bottom", i.e., through the substrate, from the face opposite the light-emitting layer. Whether the OLED is designed to emit light through the top or the bottom, the respective structure between the viewer and the light-emitting material needs to be sufficiently transparent, or at least semi-transparent, to the emitted light. In many applications it is advantageous to employ an OLED display having topside light output. This permits the display to be built on top of a silicon driver chip for active matrix addressing.

The color of light emitted from the OLED can be controlled by the selection of the organic material. White light is produced by generating blue, red and green lights simultaneously. Specifically, the precise color of light emitted by a particular structure can be controlled both by selection of the organic material as well as by selection of impurities, or dopants, added to the organic materials. By changing the kinds of organic solids making up the light-emitting layer, many different colors of light may be emitted, ranging from visible blue, to green, yellow, and red.

The color of light emitted from an OLED may be affected not only by the source material and/or doping of the light-emitting layer, but also by color filters, color converters or color changing films that are formed above the OLED pads or light-emitting layers.

OLEDs have a number of beneficial characteristics. These include a low activation voltage (about 5 volts), fast response when formed with a thin light-emitting layer, and high brightness in proportion to the injected electric current. OLEDs are currently the subject of aggressive investigative efforts.

Although substantial progress has been made in the development of OLEDs to date, additional challenges remain. For example, fabrication of color OLED displays generally

requires side-by-side patterning of red, green and blue sub-pixels. Since these devices are extremely moisture sensitive, any kind of wet processing is normally not possible. Moreover, suitable red, blue and green color emitter materials, with good color gamut and lifetime, have not yet been realized. Because of these limitations in emitter materials, most color OLED displays are fabricated using either color filters or color changing media (CCM). In the case of a bottom-emitting device where the substrate is transparent, the color filter or CCM pattern can be fabricated on the same substrate as the OLED, prior to the deposition of the OLED layers. In the case of a top-emitting device, where the silicon substrate is non-transparent and integrates all drivers, this is not possible. For top-emitting devices, the OLED layers are deposited on the silicon substrate and the color filter or CCM layers are patterned separately on a different transparent substrate. The two substrates are hermetically sealed together after accurate alignment. Figure 1 shows a typical arrangement.

In particular, a problem arises in the case of very high resolution (e.g. SXGA with 1280 x 1024 lines) head wearable displays that may be less than an inch in diagonal. The alignment accuracy required between the two substrates is typically about 0.5 μm. This poses a serious engineering challenge and can be very expensive.

Accordingly, there is a need for an OLED design that provides adequate color displays without stringent alignment tolerances. In addition, an OLED design that permits wet processing methods, which are cheaper and easier to use in manufacturing, is needed.

The present invention meets these needs and provides other benefits as well.

Objects of the Invention

It is therefore an object of the present invention to provide an economical, simple manufacturing process for a color OLED display.

It is another object of the present invention to provide a color OLED display that may be fabricated using wet processing methods.

It is yet another object of the present invention to provide an improved miniature color OLED display.

It is still another object of the present invention to provide a color OLED display with reduced alignment tolerances.

It is a further object of the present invention to provide a head wearable color OLED display with reduced alignment tolerances.

It is yet a further object of the present invention to provide a very high resolution color OLED display with reduced alignment tolerances.

It is still a further object of the present invention to provide a top-emitting color OLED display with reduced alignment tolerances for the OLED layers and the color changing media layers.

It is another object of the present invention to provide a color OLED display having a passivation layer.

It is yet another object of the present invention to provide a color OLED display with the OLED layers passivated by a transparent layer.

It is still another object of the present invention to provide a color OLED display having a passivation layer that is hydrophobic.

It is a further object of the present invention to provide a color OLED display with a layer of getter material deposited between the OLED layer and the passivation layer.

It is yet a further object of the present invention to provide a color OLED display that may be hermetically sealed using a simple glass cover.

It is still a further object of the present invention to provide a color OLED display having the color patterns applied using the alignment marks on the silicon wafer.

Additional objects and advantages of the invention are set forth, in part in the description which follows and, in part, will be apparent to one of ordinary skill in the art from the description and/or from the practice of the invention.

Brief Summary of the Invention

As illustrated in the accompanying drawings and disclosed in the accompanying claims, the invention is a color organic light-emitting video display device. The color organic light-emitting display device may comprise: a substrate; a plurality of organic light-emitting diode drivers for emitting light, arranged in a matrix and integrated into the substrate; means for passivating the organic light-emitting diode drivers, formed in contact with the substrate and the organic light-emitting diode drivers; means for changing the color of the light emitted from the organic light-emitting diode drivers, formed in contact with passivation means; and a cover for

protecting the organic light-emitting diode drivers, the passivation means, and the color changing means, hermetically sealed to the substrate. The substrate may be a silicon wafer.

In an embodiment of the present invention, the passivation means may be a passivation layer. In this embodiment, the passivation layer may be a transparent and hydrophobic material. The material for the passivation layer may be selected from the group of silicon dioxide, silicon carbide and silicon nitride. Alternatively, the material for the passivation layer may be a transparent organic material that does not retain moisture, wherein the transparent organic material is a fluoropolymer.

In an alternate embodiment of the present invention, the passivation means may be a getter layer formed in contact with the substrate and the organic light-emitting diode drivers and a passivation layer formed in contact with the getter layer. In this alternate embodiment, the getter layer is transparent and may be MgO.

The present invention is directed to a color display device wherein the color changing means may comprise color filters or color changing media. The color changing means may be patterned on the passivation means using the alignment marks on the substrate and may be patterned using wet processing methods. The cover may be aligned to the substrate without stringent alignment tolerances.

The present invention is also directed to a color display device wherein the display device is capable of providing a resolution of 1280 x 1024 lines, is suitable for a head wearable display, and is less than 1 inch in diagonal.

The present invention is also directed to a method for fabricating a color organic light-emitting display device, comprising the steps of: fabricating a substrate; forming organic light-emitting diode drivers in a matrix array in contact with the substrate; forming a passivation means in contact with the substrate and the organic light-emitting diode drivers; patterning color changing means lithographically on the passivation means, wherein the color changing means comprises at least one of (a) color filters, and (b) color changing media; fabricating a glass cover for protecting the organic light-emitting diode drivers and color changing media; and sealing the glass cover hermetically to the substrate. The step of patterning the color changing means may use alignment marks on the substrate for aligning the color changing means with the organic light-emitting diode drivers and may use wet processing methods.

The method for fabricating a color organic light-emitting display device provides a top-emitting color organic light-emitting display device that permits both the organic light-emitting diode drivers and the color changing media patterns to be fabricated on the substrate. Further, the passivation means formed by the disclosed method may be a passivation layer. Alternatively, the passivation means may be a getter layer formed in contact with the substrate and the organic light-emitting diode drivers, and a passivation layer formed in contact with the getter layer.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed. The accompanying drawings, which are incorporated herein by reference, and which constitute part of the specification, illustrate certain embodiments of the invention, and together with the detailed descriptions served to explain the principles of the present invention.

Brief Description of the Drawings

The invention will now be described in conjunction with the following drawings in which like reference numerals designate like elements and wherein:

Fig. 1 depicts a perspective view of a prior art color organic light-emitting display device;

Fig. 2 depicts a perspective view of a color organic light-emitting display device according to an embodiment of the present invention having a passivation layer deposited between the silicon substrate and the glass cover; and

Fig. 3 depicts a side view of a color organic light-emitting display device according to an alternative embodiment of the present invention having a getter layer deposited between the silicon substrate and the passivation layer.

Detailed Description of the Preferred Embodiments

A known organic light-emitting device (OLED) for video display from the prior art is shown as **10** in Fig. 1. The known OLED display device **10** comprises a silicon substrate with integrated drivers **100**. Glass cover **120** is disposed on substrate **100**, and is hermetically sealed to silicon substrate **100** using seal band **110**. Color filter or color changing media (CCM) pattern **130** is applied to top surface of glass cover **120**.

The known display device **10** of Fig. 1 operates as follows: upon application of the appropriate voltage to an anode and cathode line (not shown), electrodes (not shown) in the

OLED layers, connected to the anode and cathode, emit light. The emitted light may be of a particular color, or may be white, depending on the organic material and/or doping of the OLED layer (not shown). The color of the emitted light is changed upon passing through color filter or color changing media **130**. This colored light passes through glass cover **120** providing the visual display from device **10**.

Reference will now be made in detail to preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. An embodiment of a color organic light-emitting device for video displays according to the present invention is shown as **20** in Fig. 2. This embodiment of a color OLED display device comprises substrate **200**, with OLED drivers (not shown) integrated therein. Substrate **200** preferably is silicon.

As embodied herein, passivation layer **210** is disposed on substrate **200**. Passivation layer **210** may be silicon dioxide, silicon carbide, silicon nitride, or other transparent material. Passivation layer **210** may also be formed from transparent organic materials that do not retain moisture, such as fluoropolymers.

As embodied herein, color filter or color changing media (CCM) patterns **230** may be lithographically fabricated directly on passivation layer **210**. Color patterns **230** may be patterned using the alignment marks on substrate **200** itself, using wet precessing methods.

Device **20** may then be hermetically sealed using a simple glass cover **220**, requiring no stringent alignment tolerances. Device **20** may be fabricated for head wearable application and may be a maximum of 1 inch in width by 1 inch in length. Substrate **200** and glass cover **220** may both be 0.7 mm thick.

This embodiment of the present invention operates as follows: upon application of the appropriate voltage to an anode and cathode line (not shown), electrodes in the OLED layers (not shown), connected to the anode and cathode, emit light. The color of the emitted light is changed upon passing through color filter or color changing media **230**. This colored light passes through glass cover **220** providing the visual display from device **20**.

An alternate embodiment **30** is shown in Fig. 3. In this alternate embodiment, transparent getter layer **240** is formed over the OLED layer stack **205** prior to depositing passivation layer **210**. Getter layer **240** may be composed of MgO. MgO is an excellent getter material and may prevent any moisture permeation into the OLED layers that might occur during the processing of color filter or CCM patterns **230**.

In the alternate embodiment, passivation layer **210** is deposited on getter layer **240**. As in the first embodiment, color filter or CCM patterns may be lithographically fabricated directly on passivation layer **210**, using alignment marks on substrate **200**, by wet processing methods.

In the alternate embodiment, device **30** may then be hermetically sealed using a simple glass cover (not shown), requiring no stringent alignment methods.

While this invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. For example, other transparent getter materials with properties similar to MgO may be used for the getter layer. Accordingly, the preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting.

What is claimed is:

1. A color organic light-emitting display device comprising:

a substrate;

a plurality of organic light-emitting diode drivers for emitting light, arranged in a matrix and integrated into said substrate;

means for passivating said organic light-emitting diode drivers, formed in contact with said substrate and said organic light-emitting diode drivers;

means for changing the color of said light emitted from said organic light-emitting diode drivers, formed in contact with passivation means; and

a cover for protecting said organic light-emitting diode drivers, said passivation means, and said color changing means, hermetically sealed to said substrate.

2. The display device of claim 1, wherein said substrate is a silicon wafer.

3. The display device of claim 1, wherein said passivation means is a passivation layer.

4. The display device of claim 3, wherein said passivation layer is a transparent and hydrophobic material.

5. The display device of claim 4, wherein said material for said passivation layer is selected from the group of silicon dioxide, silicon carbide and silicon nitride.

6. The display device of claim 4, wherein said material for said passivation layer is a transparent organic material that does not retain moisture.

7. The display device of claim 6, wherein said transparent organic material is a fluoropolymer.

8. The display device of claim 1, wherein said passivation means is a getter layer formed in contact with said substrate and said organic light-emitting diode drivers and a passivation layer formed in contact with said getter layer.

9. The display device of claim 8, wherein said getter layer is transparent.

10. The display device of claim 8, wherein said getter layer is MgO.

11. The display device of claim 1, wherein said color changing means comprises color filters.

12. The display device of claim 1, wherein said color changing means comprises color changing media.

13. The display device of claim 1, wherein said color changing means is patterned on said passivation means using the alignment marks on said substrate.

14. The display device of claim 1, wherein said color changing means is patterned using wet processing methods.

15. The display device of claim 1, wherein said cover is aligned to said substrate without stringent alignment tolerances.

16. The display device of claim 1, wherein said display device is capable of providing a resolution of 1280 x 1024 lines.

17. The display device of claim 1, wherein said display device is suitable for a head wearable display.

18. The display device of claim 1, wherein said display device is less than 1 inch in diagonal.

19. A method for fabricating a color organic light-emitting display device, comprising the steps of:

fabricating a substrate;

forming organic light-emitting diode drivers in a matrix array in contact with said substrate;

forming a passivation means in contact with said substrate and said organic light-emitting diode drivers;

patterning color changing means lithographically on said passivation means, wherein said color changing means comprises at least one of (a) color filters, and (b) color changing media;

fabricating a glass cover for protecting said organic light-emitting diode drivers and color changing media; and

sealing said glass cover hermetically to said substrate.

20. The method of claim 19, wherein said step of patterning said color changing means uses alignment marks on said substrate for aligning said color changing means with said organic light-emitting diode drivers.

21. The method of claim 19, wherein said step of patterning said color changing means uses wet processing methods.

22. The method of claim 21, wherein said method provides a top-emitting color organic light-emitting display device that permits both said organic light-emitting diode drivers and said color changing media patterns to be fabricated on said substrate.

23. The method of claim 20, wherein said passivation means is a passivation layer.

24. The method of claim 20, wherein said passivation means is a getter layer formed in contact with said substrate and said organic light-emitting diode drivers, and a passivation layer formed in contact with said getter layer.

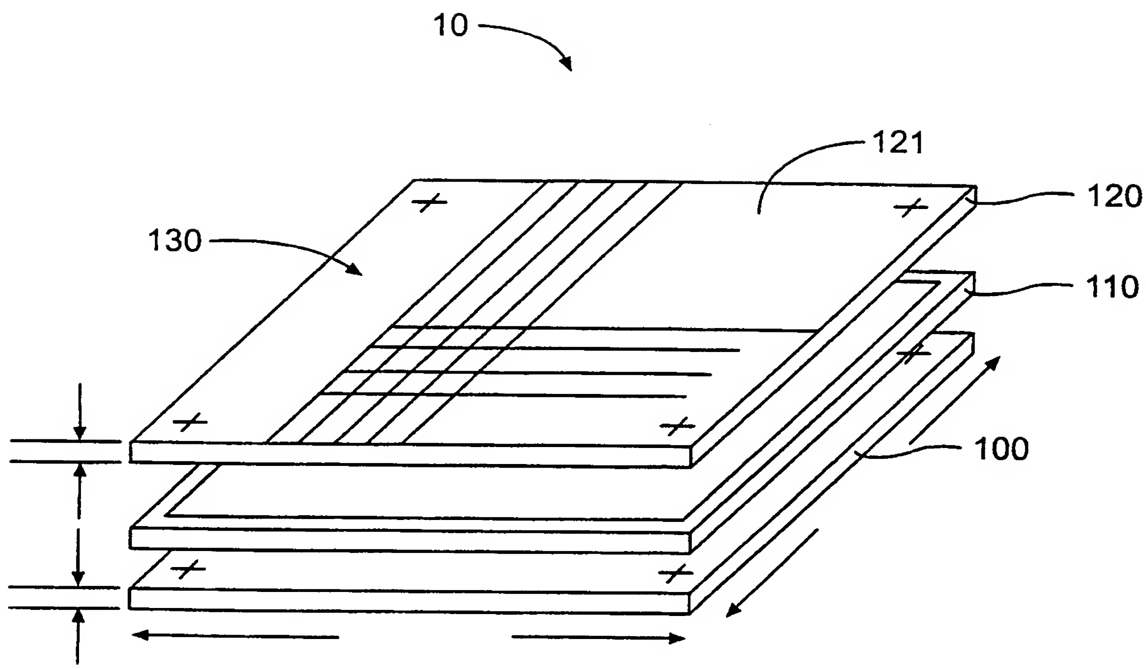

FIG. 1
PRIOR ART

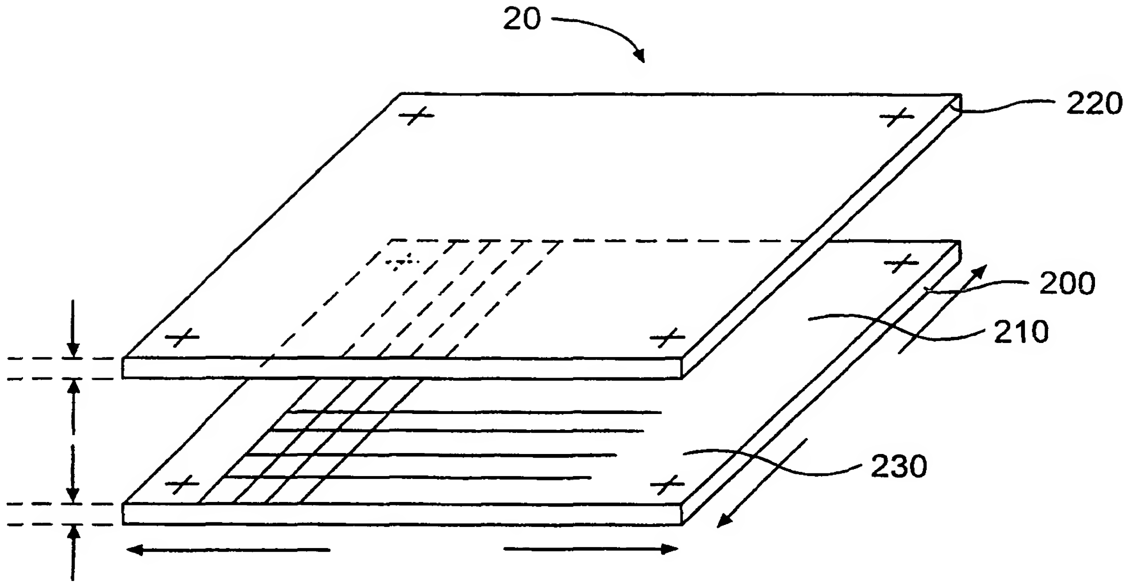

FIG. 2

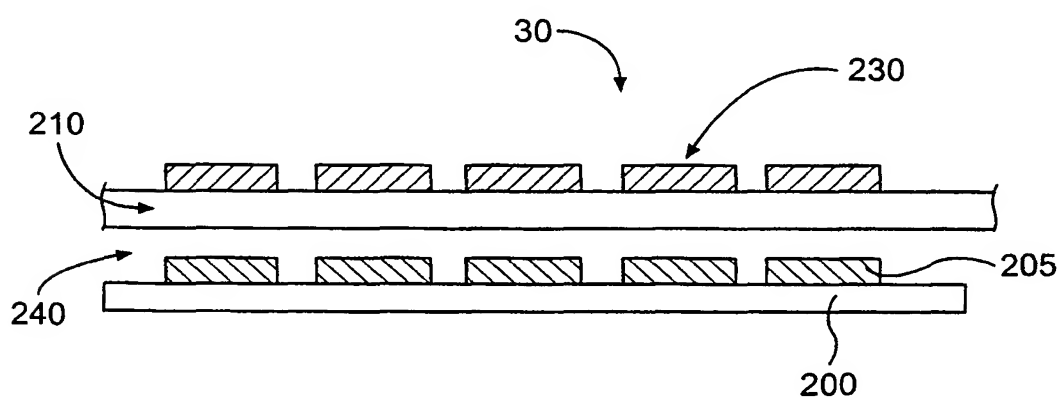

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/21936

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B23B 7/02
US CL :313/506
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 313/506, 500,501,504,505; 427/58,68,69

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,731,661 A (SO et al) 24 March 1998 (24/03/98) Fig. 3; col. 2, line 48 - col. 3, line 9	1-18
A	US 5,757,126 A (HARVEY, III et al), 26 May 1998 (26/05/98) Fig. 11; col. 6, lines 29- 67	1-18
A	US 5,641,611 A (SHIEH et al) 24 June 1997 (24/06/97) Fig. 1-7; col. 3, line 2 - col. 4, line 57.	19-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
06 JANUARY 2000	31 JAN 2000

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